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2.2 Scientific and technical description of the results

Survey of the market for biomass fuelled cogeneration in participating European countries (Deliverable 3 under Work Package 3)

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1. Introduction

This interim report under BIOCOGEN Work Package 3 “Analysis of the market for biomass cogeneration” reviews:

- Biomass fuel potential
- Applications of biomass cogeneration
- Drivers and barriers

These issues are reviewed with reference to the wider (primarily fossil fuel) cogeneration market. The report aims to determine the main current features, anticipated trends, pan-European similarities and differences between countries.

2. An overview of cogeneration

Cogeneration technologies

Cogeneration is used on many thousands of sites throughout the EU and supplies around 10% of both the electricity generated and heat demand in the EU. It is an established technology and its ability to provide a reliable and cost-effective supply of energy has been proven. The following overview of the applications of cogeneration is primarily sourced from "A Guide to Cogeneration" (COGEN Europe, 2001).

Cogeneration has a long history of use in many types of industry, particularly in the paper and bulk chemicals industries, which have large concurrent heat and power demands. In recent years the greater availability and wider choice of suitable technology has meant that cogeneration has become an attractive and practical proposition for a wide range of applications. These include the process industries, commercial and public sector buildings and district heating schemes, all of which have considerable heat demand. The three main applications of cogeneration - industrial sites, district heating and individual buildings - are outlined in the box below.

Main applications of cogeneration

Industrial cogeneration
Schemes are typically located on sites that have a high demand for process heat and electricity all year. Suitable examples are found in the refining, paper, chemicals, oil, greenhouses and textile sectors. The bulk of cogeneration capacity on industrial sites come from schemes of over 1 MWe, and these tend to be designed on an individual basis to meet the specific requirements of each application. A much larger number of industrial sites have smaller systems, using technologies similar to the cogeneration systems used in buildings and commerce. Although numerous, these account for lower levels of total capacity

District heating.
The heat provided by cogeneration is ideal for providing space heating and hot water for domestic, commercial or industrial use. The use of district heating networks is common in urban areas in northern, central and eastern Europe where the colder and longer winters require longer heating seasons, and hence entail longer running periods for the heating system. Engines, providing electricity and heat, in combination with boilers, can introduce more cogeneration into existing networks. A feature of cogeneration driven district heat is the option of fuel diversity to suit environmental, economic or strategic priorities. For example, district heating systems are sometimes based on the incineration of municipal waste which, with adequate emission controls, is a better environmental solution than disposing waste to landfill. Other biomass fuels are also used, particularly wood and straw.

Individual buildings - residential and commercial.
Cogeneration systems used tend to be smaller systems, often based on 'packaged' units. All equipment is housed in an acoustic container and the only connections to the unit are for fuel, normally natural gas, and the connections for the heat and electricity output of the unit. These systems are commonly used in hotels, leisure centres, offices, smaller hospitals, and multi-residential accommodation. Larger applications are based on technology that is similar to the cogeneration systems used in industry, gas turbines, or larger reciprocating engines. Such systems are used in larger hospitals, large office complexes, universities and colleges.

It is evident from the above that cogeneration provides a range of outputs. Indeed, it can provide output from 1 kWe to 500 MWe. The box below summarises the terminology typically used for different scales, though one person's small system may be another's large and the terms used vary.

Scales of cogeneration
Cogeneration. **Large** is considered to be more than 10MWe. Such plant is used for industrial and district heating. **Medium** is from 1 MWe to 10 MWe. Plants for industrial applications typically fall into the range 1-50 MWe, although some larger systems have been installed. For applications greater than around 1 MWe there is no "standard" cogeneration kit: equipment is specified to maximise cost-effectiveness for each individual site. For small-scale cogeneration applications, equipment is normally available in pre-packaged units, helping to simplify installations. Everything under 1 MWe can be considered **small**-scale. "**Mini**" is under 500 kWe and "**micro**" under 20 kWe. Non industrial applications cover also a full range of sizes, from 1 kWe for a domestic dweling to about 10 MWe for a large district heating cogeneration scheme.

A notable recent development is trigeneration, the conversion of a single fuel source into three energy products: electricity, steam or hot water and chilled water. Trigeneration can be applied to all the applications of cogeneration: district cooling; industry; individual buildings. An outline is given in the box below.

The barriers facing development of CHP plants combined with cooling can be even more severe than the barriers for CHP plants. For the time being, it increases the costs of the system considerably. Nevertheless there is an expectation that this type of application will increase substantially in the next few years

Trigeneration

A single fuel source can be converted into three energy products - electricity, steam or hot water and chilled water – with lower pollution and greater efficiency than producing the three products separately. A conventional cogeneration system can be coupled with a chiller either by compression (using heat to create cooling) or by absorption (cogeneration to drive refrigeration compressors). Trigeneration can be applied to all the applications of cogeneration: district cooling; industry; individual buildings.

In recent years district cooling has been considered in many locations as a method for meeting the space cooling requirements of buildings in the residential, commercial and, at times, industrial sector. It is particularly suitable in urban areas with high density arrangement offices and residential dwellings requiring air conditioning. District cooling is a recent concept, but is already relatively widely used in the USA and Japan. In Europe, there is awareness of the technology, but there is certainly less experience –with the possible exception of Sweden. An additional barrier that these systems face in Europe, apart of the fact that installing cooling increases the initial costs of the system considerably, is that the most suitable applications will be found in the South of Europe, which means, in countries where there is less experience of district heating (and where networks would have to be built), and hence less history among consumers or suppliers of the provision of this type of central energy.

Many industries, in particular the food industry, lack sources of cold water during summer. For deep-frozen food manufacturers, refrigeration demand for storage temperatures from -20°C to –30°C exist all year around.

Cooling might also be delivered to individual hotels, sport and leisure centres and residential accommodation. The CHP system can be configured to run during the summer months, when the lower demand for heating would otherwise reduce the opportunity for system operation.

Biomass cogeneration technologies

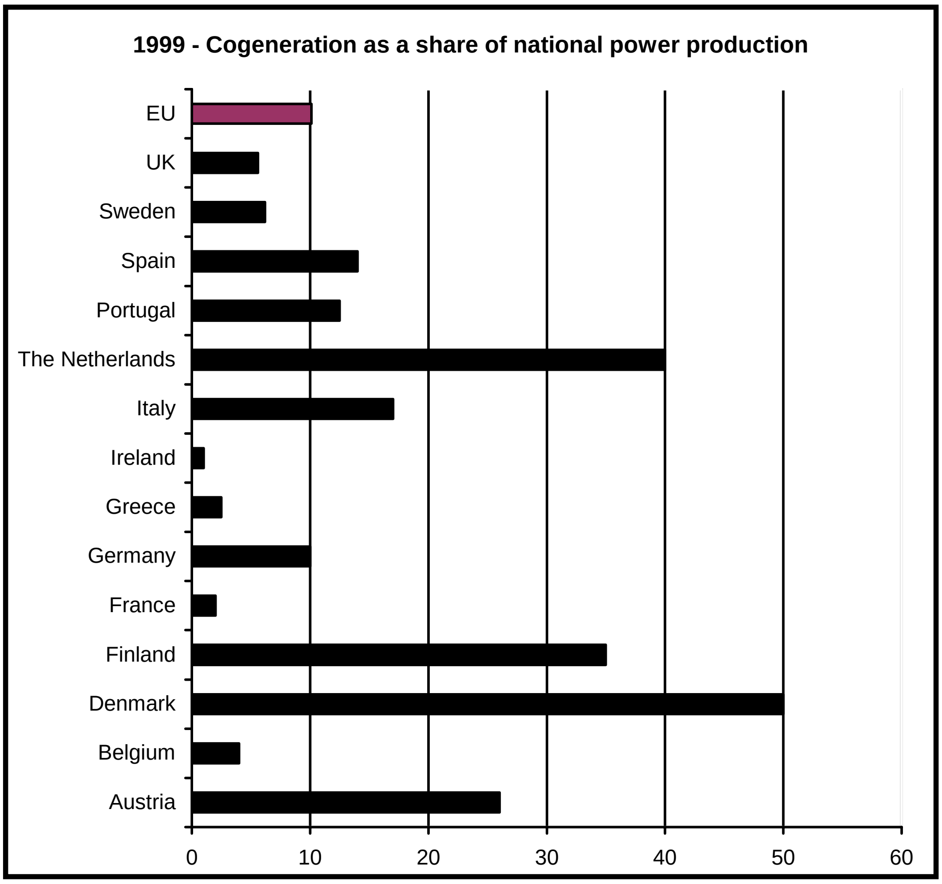
Theoretically, almost any fuel is suitable for cogeneration. Fossil fuels especially natural gas predominate for economic reasons but various forms of biomass are already important.

Biomass cogeneration exists on large scale. Commercial operation of what is believed to be the world's largest biomass cogeneration plant began in December 2001 (Nickull, 2002). The plant is located in Jakobstad/Pietarsaari, Finland. The plant uses wood-based biofuel - bark, sawdust, wood chips - and cut peat, along with coal as a reserve fuel. The electrical capacity of the new power station will be 240 MW in full condensing operation. The unit will also produce, during its normal operation, a maximum of 100 MW process steam and 60 MW of district heating. This plant has several novel features: the multi-fuel power plant concept; novel technology for solid multi-fuel; co-firing of biomass with fossil fuel; and large scale. The plant can export power when demand for heat is low. The plant varies its fuel inputs according to season and fuel prices.

TO BE COMPLETED

Current cogeneration market and anticipated trends

The share of cogeneration in electricity production in Europe is about 10%. Cogeneration in the European Union is characterised by wide diversity in the scale and nature of development. This diversity reflects differences in history, policy priorities, natural resources, culture and climate and has close links with the structure and activity of electricity markets. The figure below presents the state of development of cogeneration in the different countries. This is sourced from COGEN Europe, which notes that countries collect data in different ways.



The graph above may be compared to biomass cogeneration installed capacity data presented in the report for BIOCOGEN Work Package 4: Survey of biomass cogeneration in Europe. For example, Austria has well-established cogeneration and biomass cogeneration markets.

COGEN Europe considers current installed capacity to be far below full potential, which it estimates to be at least 30%. A recent study, titled Future Cogen, was completed in 2001 (ESD, 2001). This was an assessment of the current status and future markets for cogeneration in 28 European countries under a range of market scenarios. The work also included an assessment of the effects of increased cogeneration on greenhouse gas emissions. The results of the work are shown in the graphs below. The four scenarios studied are outlined in the box below.

Future Cogen: four scenarios

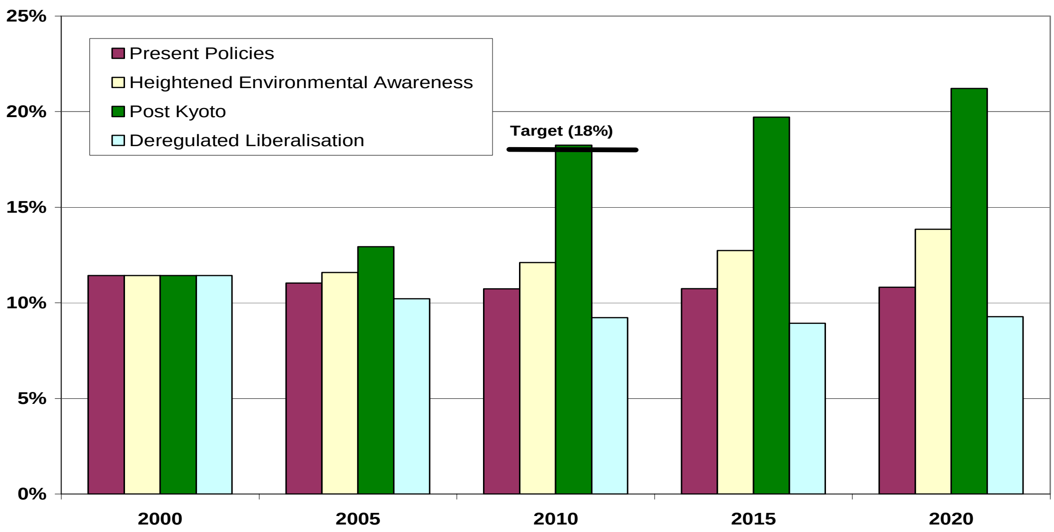
Present policies. Current policies in the energy sector continue, particularly those that affect cogeneration, including changes expected to happen. Energy sector liberalization in Europe is expected to be complete by 2010. Technological developments will be evolutionary, as opposed to revolutionary.

Heightened environmental awareness. Based upon present policies but with additional benefits for "green" technologies. This includes the internalization of the external benefits of cogeneration through the introduction of a carbon tax and faster technological developments.

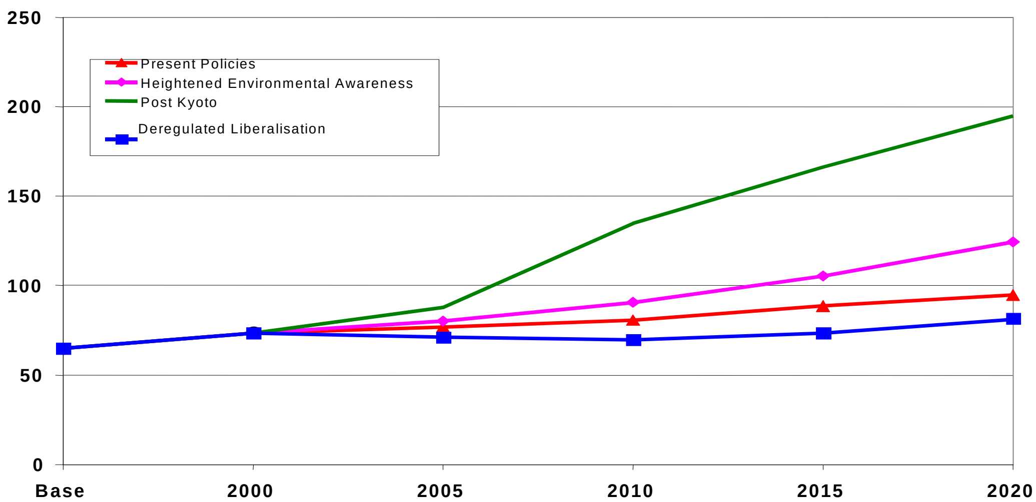
Deregulated liberalization. Liberalisation continues but with no protection for smaller scale decentralised generation capacity. The electricity market is expected to be dominated by only a few centralised generators, who strongly influence electricity prices. The net result is that cogeneration could become non-competitive.

Post-Kyoto. The benefits of cogeneration are internalized into the costs. An increased amount of investment into cleaner technologies worldwide, in a world tied to the Kyoto Protocol targets. Flexible mechanisms provide new finance sources. Micro generation becomes possible and fuel cell cogeneration becomes possible. Economic and energy policies are focused on decentralised generation.

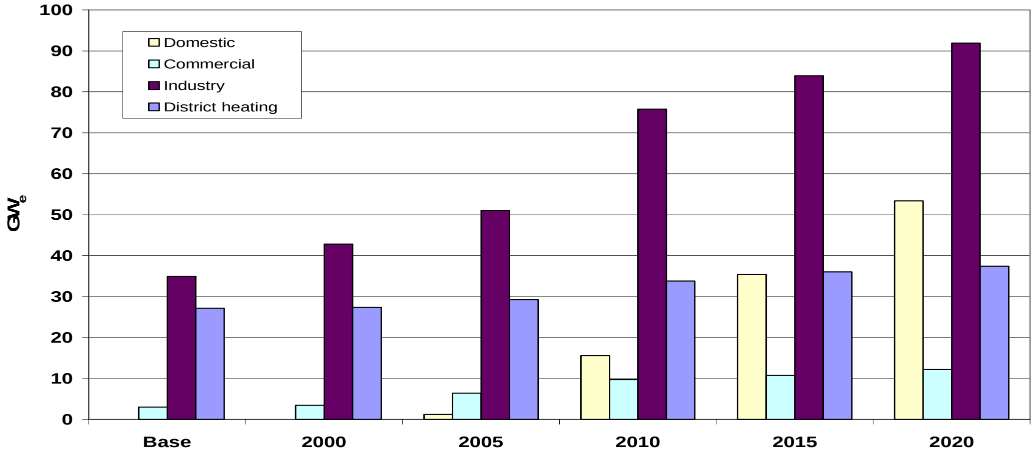
EU Cogeneration Electricity Output - proportion of gross electricity consumption (%)



EU Cogeneration Electricity Capacity (GWe)



EU Cogeneration Capacity by Sector (GWe) under Post Kyoto scenario



The scenarios show widely different future prospects for cogeneration. The cogeneration market has become static – the reasons for this are discussed further below in the section on barriers – and under current policies a small decrease in capacity is forseen. The post Kyoto scenario is the best. Under this scenario, the model showed there is potential to:

- double cogeneration capacity by 2010
- supply 22% of generated electricity in the EU by 2020
- increase capacity by 50% in the CEE
- save 127 million tonnes of CO2 in EU by 2010 and 258 million tonnes by 2020

It is anticipated that technological developments will open major new markets. This is evident from the forecast under Post-Kyoto scenario showing domestic sector cogeneration increasing from zero in 2000 to very significant capacity by 2020. This forecast is based on anticipated rapid developments in micro generation technologies using natural gas. These technologies are anticipated to become financially attractive and their market penetration to be rapid, firstly in those countries with existing extensive natural gas networks (UK, Germany, Netherlands) and then in other countries as gas becomes more widespread.

Biomass cogeneration related technological developments are also likely, and the question of whether and how biomass cogeneration might fit with these future trends is explored further below. Future Cogen concluded that natural gas will be the future fuel of choice but biomass fuels will be significant. It concluded that biomass in the EU could provide up to 11000 MWe by 2010 (ie. around 12% of the total cogeneration capacity 135000 MWe) with a further 8000 MWe by 2020 (ie. around 10% of the total cogeneration capacity 195000 MWe).

3. Potential biomass fuel resources

This section provides a summary of quantities of potential biomass (solid, liquid and gas) estimated to be available for fuel in each participating country, in addition to the resources that are already exploited for energy use. The following broad categories of resource were considered:

- Agriculture
- Forestry
- Energy crops
- Waste
- Sewage

Principle sources / residues considered under each broad resource category

Category of biomass residue	Main sources / biomass residues
Agriculture	All residues remaining in-situ from agriculture production, including straw from cereal production; animal manures; stalks from cotton, maize etc; stems & leaves from sugar beet, tobacco etc; prunings from vines, fruit trees etc. All residues produced as by-products from processing agriculture crops such as cotton processing; food canning; olive oil processing; meat processing; wine making
Forestry	All non-merchantable wood - small diameter roundwood, branches/brash, tops – left in-situ by thinning and harvesting operations. Includes short rotation forestry. All non-treated residues – chips, bark etc – from primary and secondary processing of wood: saw mills; furniture making; pulp and paper mills; fiber board mills
Energy Crops	Potential annual or perennial dedicated energy crops. Trees grown on short rotation coppice (willow, poplar etc); grasses etc (giant reed, switchgrass, miscanthus, cardoon, Spanish thistle artichoke).
Waste	Untreated wood residues excluding those from wood processing industry (eg. wood pallets and packaging, demolition wood). The organic fraction of waste from households, commerce, industry.
Sewage	Potential biogas production from sewage treatment

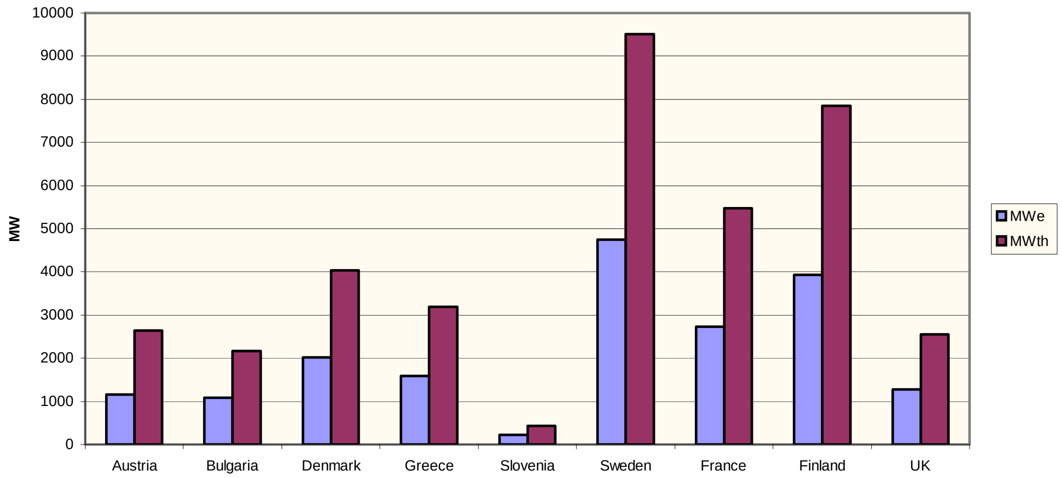
BIOCOGEN partners and industry contacts provided quantitative estimates with observations on when fuel supply might be realized. The responses are included in the annexes. A summary table is provided below. This table also includes estimates of the potential biomass cogeneration capacity that could installed based on this fuel availability. This makes two (conservative) assumptions regarding conversion, namely plants operate for 6000 hours per year and with 75% fuel efficiency. Power:heat ratio is estimated to be 1:2. The data is described with graphs below.

Potential biomass fuel resources, excluding biomass already exploited for energy production

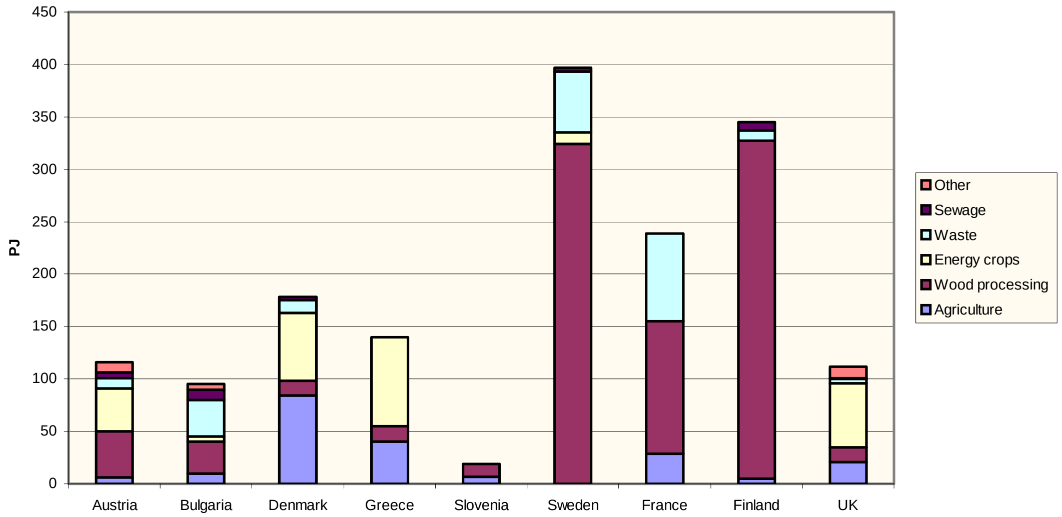
	Estimated available resource in the long term ie 10 years plus (PJ)	Estimated potential biomass cogeneration installed capacity (MW)		
		MW fuel	**MW e**	**MW th**
Austria				
Agricultural residues	6	276	68	137
Wood processing	44	2024	501	1002
Energy crops	41	1886	467	934
Waste	10	460	114	228
Sewage	5	230	57	114
Other	10	460	114	228
Total	116	5336	1150	2641
Bulgaria				
Agricultural residues	10	460	114	228
Wood processing	30	1380	342	683
Energy crops	5	230	57	114
Waste	35	1610	398	797
Sewage	10	460	114	228
Other	5	230	57	114
Total	95	4370	1082	2163
Denmark				
Agricultural residues	84	3864	956	1913
Wood processing	14	626	155	310
Energy crops	65	2990	740	1480
Waste	12	538	133	266
Sewage	3	133	33	66
Total	177	8151	2017	4035
Finland				
Agricultural residues	5	230	57	114
Wood processing	322	14812	3666	7332
Energy crops				
Waste	10	460	114	228
Sewage	8	368	91	182
Total	345	15870	3928	7856
France				
Agricultural residues	29	1334	330	660
Wood processing	126	5796	1449	2898
Energy crops				
Waste	84	3864	956	1913
Sewage				
Total	239	10994	2735	5471
Greece				
Agricultural residues	40	1840	455	911
Wood processing	15	690	171	342
Energy crops	85	3910	968	1935
Waste				
Sewage				
Total	140	6440	1594	3188
Slovenia				
Agricultural residues	7	322	80	159
Wood processing	12	552	137	273
Energy crops				
Waste				
Sewage				
Total	19	874	216	433
Sweden				
Agricultural residues		989	245	490
Wood processing	324	14904	3689	7377
Energy crops	11	497	123	246
Waste	58	2650	656	1312
Sewage	4	161	40	80
Total	396	19200	4752	9504

UK				
Agricultural residues	21	966	239	478
Wood processing	14	644	159	319
Energy crops	61	2806	694	1389
Waste	4	184	46	91
Sewage	1	46	11	23
Other	11	506	125	250
Total	112	5152	1275	2550

Cogeneration capacity estimated from currently unexploited biomass fuel potential



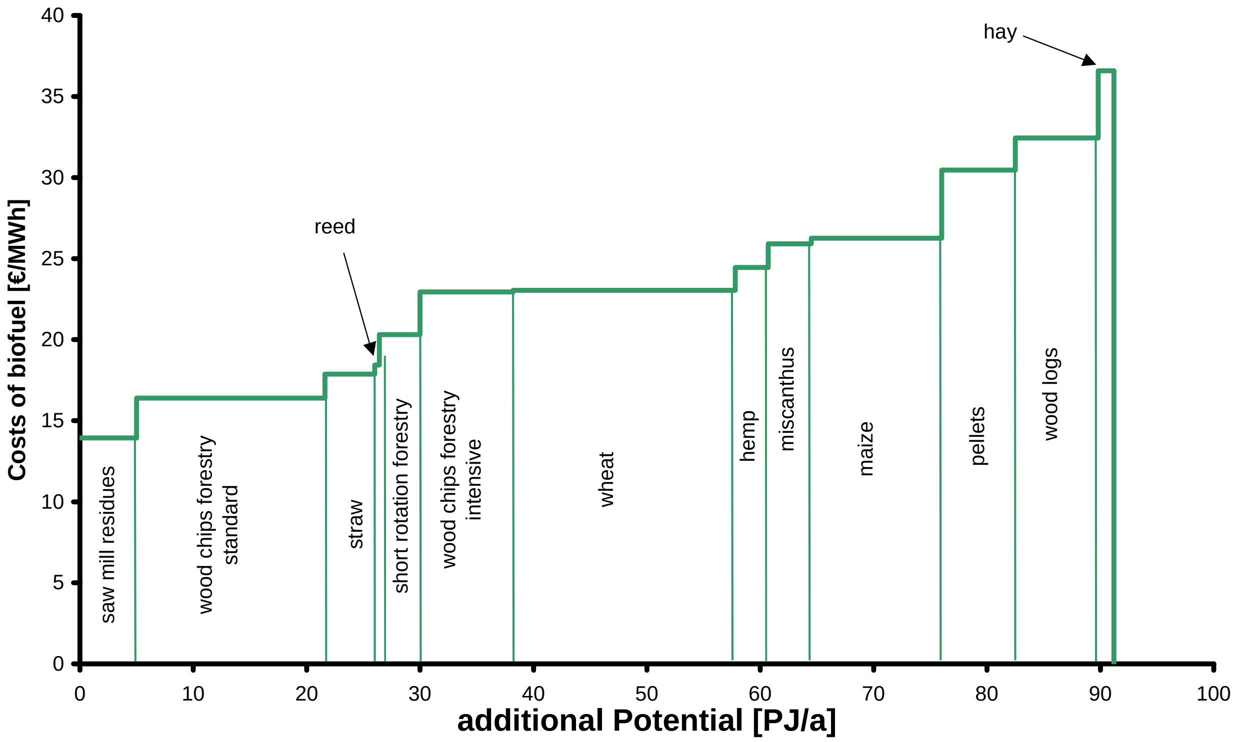
Currently unexploited biomass fuel potential



The data illustrate the theoretical abundance of biomass fuels. The data above is for eight countries. Waste and sewage data are not available for Slovenia and there is no data for Turkey. The data indicate over 1300 PJ biomass fuel available in the longer term (>10 years) in the eight countries included. This is (very approximately) estimated to be sufficient fuel for around 15000 MWe biomass cogeneration capacity.

Data is generally quite scant and, most importantly, it is difficult to compare across countries. Some countries have comprehensive collection and modeling of biomass fuel uses, potentials and costs. An example is given below for Austria (source: Jungmeier et al, 2002). Scandinavian countries also have good data.

Biomass in Austria: the costs and potential of fuels from forestry, wood industry and agriculture additional to current use (source: Jungmeier et al, 2002).



Waste-related biomass data is scant. Cogeneration plants exist in sewage works and there is thought to be scope for further capacity, particularly in Southern and Central and Eastern Europe. This is also true for landfill gas, which is well developed in Northern European countries but not yet elsewhere in Europe. The organic fraction of municipal solid waste may be a fuel for cogeneration, using incineration, anaerobic digestion etc.

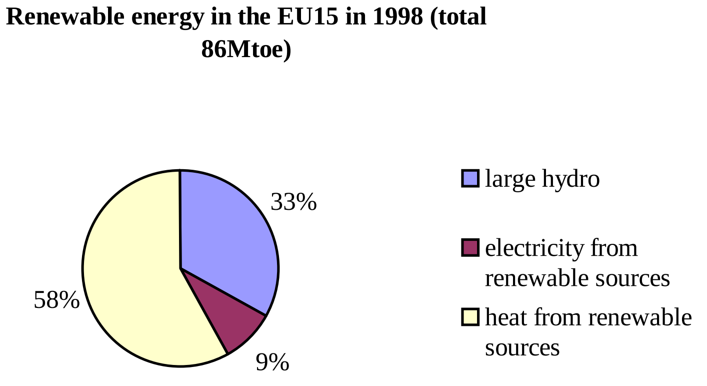
Most countries do not have data for wood from construction and demolition industries. Construction is a big user of raw wood and it might be assumed that wood arising from demolition might be significant where timber is used in the actual constructions. Both these sources are disparate and wood waste might be largely contaminated. Nonetheless, these need to be considered.

The potential biomass supplies from energy crops depend on assumptions regarding future Common Agriculture Policy on farm subsidies, set-aside etc. The numbers can be very large, indeed an order of magnitude greater than other sources. This needs to be approached through a couple of scenarios with agreed assumptions.

4. The potential market for biomass cogeneration

This section considers the potential market for biomass cogeneration, by considering where cogeneration units may be installed and the number and capacity range for such installations.

In terms of primary energy, heat from renewable sources is some six to seven times greater than electricity from renewable sources (excluding large hydro), and the heat is virtually all from biomass.



The section below considers sites that have current or anticipated future suitability for cogeneration with any fuel. The box below lists potential applications for cogeneration with any fuel. These cover all the main economic sectors: industrial; public / government; residential and commercial.

Sites for application of cogeneration

- Horticulture and glasshouses*
- Municipal solid waste management*
- Waste water and sewage treatment*
- Agro-industries*
- Wood processing*
- Paper and board manufacture*
- District heating*
- Brewing, distilling & malting
- Ceramics
- Brick
- Cement
- Food processing
- Textile processing
- Minerals processing
- Oil Refineries
- Iron and Steel
- Motor industry
- Pharmaceuticals & fine chemicals
- Hotels
- Hospitals
- Leisure centres & swimming pools
- College campuses & schools
- Airports
- Prisons, police stations, barracks etc

- Supermarkets and large stores
- Office buildings
- Individual houses

The survey by BIOCOGEN indicated a range of applications with immediate potential for biomass cogeneration, these are indicated in the list above with an asterisk *. A brief outline review of the BIOCOGEN country studies (see table below) shows that there is existing experience of using biomass cogeneration in these applications. It must be noted that this simple overview conceals the huge diversity of biomass generation plants existing. In most instances, the numbers of installations are very limited. Exceptions include wood processing, pulp and paper, and district heating – and in these cases units are largely geographically confined to Scandinavia. Although there are small numbers of units, a great diversity of scales and technologies are in use. For example, waste treatment includes incineration (Turkey), landfill (Denmark) and anaerobic digestion (Denmark, combined wastes from household and agriculture sources). Clearly there are many demonstration and trial plant and this is obviously a picture of an industry in its early stages of development.

Existing biomass cogeneration sites by application (data summary from the BIOCOGEN country studies)

	Waste treatment	Sewage treatment	Agro-industries	Wood industries	Pulp & paper	District heating	Other
Slovenia		X		X			
Bulgaria						X	
France		X	X		X		
Turkey	X	X					
Finland				X	X	X	
Denmark	X		X			X	Individual housing
UK		X		X			Food industry, individual buildings
Austria				X		X	
Sweden				X		X	
Greece							
Belgium							
Germany						X	
Spain					X	X	
Portugal				X			
Netherlands						X	Individual buildings (leisure center)
Ireland							Individual user (greenhouses)

With the exception of district heating, favoured applications for biomass cogeneration all have available biomass materials on site, either biomass residues are generated on site as a by-product or these industries deal with waste biomass materials. Many of these sites use heat and often there is long experience of the generation of heat-only from biomass combustion.

There are many cogeneration opportunities in the wood processing industry with sub-sectors including:

- Primary wood processing (including sawmills and board mills)
- Pulp and paper mills
- Secondary processing (such as furniture manufacture)

Use of biomass cogeneration already exists in some of these industries. The majority of large pulp and paper mills have biomass cogeneration plant. The reason that cogeneration is widespread in this industry is self-evident: these mills have, on the one hand, huge quantities of residues that would be very costly to dispose and, on the other hand, huge heat and power demand. Increasing restrictions on disposal is also becoming a driver for cogeneration to be installed at other wood processing sites that generate residues. This is a more important factor for those industries with larger quantities of residues. The energy demand, and particularly the need for heat, is also an important consideration. Reasons for and against investment in cogeneration are reviewed further below.

Scale of activities and energy, particularly heat, demand are also important in agro-industries. The primary interest is in those industries with individual sites that have sizeable quantities of solid and / or liquid residues and significant energy demand, particularly heat. The nature of such agro-industries varies between Northern and Southern Europe. In Northern Europe, poultry and livestock rearing are often intensive and relatively large-scale. In Southern Europe, cotton-ginning, olive processing, fruit canneries and rice mills are potential sites. There is interest in using several sites to deliver fuel to a centralised generation site, where there is an existing large heat demand and to achieve economies of scale. For example, centralised anaerobic digestion plants are being developed. These are supplied with animal slurries collected from several farming units plus perhaps digestible food wastes from other sources.

There are considerable opportunities for cogeneration in the waste management industry, including:

- Landfill gas
- Waste incineration (gasification and pyrolysis)
- Sewage gas

Power generation from landfill gas can directly compete with conventional power and is commercially attractive, particularly if there are added incentives for mitigation of greenhouse gas emissions / renewable energy. It is therefore well developed in northern Europe. There is potential for considerable additional capacity in Southern and Central and Eastern Europe, where power markets are opening up and sanitary landfills are being established. However, most landfill gas is power-only, not cogeneration, because local heat demands are limited.

Many forecasts indicate a large increase in the number of waste incineration installations throughout Europe, due to the various pressures to reduce waste disposed to landfill. There is considerable experience in generating heat for nearby residential areas and power from incineration sites. The fuel in this case of course comprises both biomass and non-biomass materials.

Sewage gas, produced from anaerobic digestion of sewage, has been used as an energy source since early 1900s. Sewage gas is a cost-effective option in many places as a by-product of sewage waste treatment. Energy from sewage gas typically involves small scale plant. Electrical generating capacity of sewage gas cogeneration is usually no greater than 1 MW, unless the plant is installed at a very large sewage treatment works. The largest plants tend to be below 10 MW electricity capacity. There is several hundred megawatts sewage gas capacity in Europe (the European Renewable Energy Exchange estimated some 250MWe and 150MWth in EU in

1997). There is considerable potential for extending the use of cogeneration in sewage treatment plant in many European countries.

In Scandinavia, district heating plants fuelled with wood and straw are widespread. These plants typically use a diversity of local and imported biomass fuel sources - residues from forest harvesting, wood from dedicated energy crops – and may co-fire these with peat or coal. There are some opportunities for existing district heating sites to be retrofitted with cogeneration plant. Some new district heating plants are being installed and these might export power as well as heat. However, new build district heating (fuelled with biomass or any other fuel) faces significant barriers– this is reviewed further below.

Most observers believe that opportunities for installing biomass cogeneration in sites without related activities are limited. There are niche opportunities for installing biomass cogeneration in public buildings, such as museums, leisure centers, and hotels etc in rural or peri-urban locations, where a high value is placed on the environmental and other benefits and there is lesser focus on short-term financial return.

Some visionaries forsee a decentralised renewable energy-based future, with important roles for biomass in all forms. Concepts include:

- Micro-cogeneration in individual houses, using pelletised biomass fuels
- Centralised biomass conversion units, for example producing pyrolysis liquid for onward transfer to cogeneration units in commercial and public sector buildings.
- Multiple fuelling, such as cogeneration plant on waste management sites using gas from anaerobic digestion of organic waste, gas from landfilled waste, supplemented by synthesis gas from gasification of local biomass material.
- Use of the heat supplied by biomass fuelled CHP in summer months for liquifaction of biomass and ethanol production.

Clearly huge developments, not least technological advances, will be necessary for such a future.

5. The drivers in the biomass cogeneration market

Why promote biomass cogeneration?

From the policy-maker's viewpoint, cogeneration offers a number of national and international benefits, due largely to its high fuel-use efficiency and its decentralised nature. Benefits are outlined in the box below (source: A Guide to Cogeneration).

Benefits of Cogeneration

- Increased efficiency of energy conversion and use: cogeneration offers energy savings ranging between 15-40% when compared against the supply of electricity and heat from conventional power stations and boilers;
- Lower emissions to the environment, in particular of CO2, the main greenhouse gas;
- In some cases, where there are biomass fuels and some waste materials such as refinery gases, process or agricultural waste (either anaerobically digested or gasified), these substances can be used as fuels for cogeneration schemes, thus increasing the cost-effectiveness and reducing the need for waste disposal;
- Large cost savings, providing additional competitiveness for industrial and commercial users, and offering affordable heat for domestic users;
- An opportunity to move towards more decentralised forms of electricity generation, where plant is designed to meet the needs of local consumers, providing high efficiency, avoiding transmission losses and increasing flexibility in system use. This will particularly be the case if natural gas is the energy carrier;
- Improved local and general security of supply - local generation, through cogeneration, can reduce the risk that consumers are left without supplies of electricity and/or heating. In addition, the reduced fuel need which cogeneration provides reduces the import dependency - a key challenge for Europe's energy future;
- An opportunity to increase the diversity of generation plant, and provide competition in generation. Cogeneration provides one of the most important vehicles for promoting liberalisation in energy markets;
- Increased employment - a number of studies have now concluded that the development of cogeneration systems is a generator of jobs.

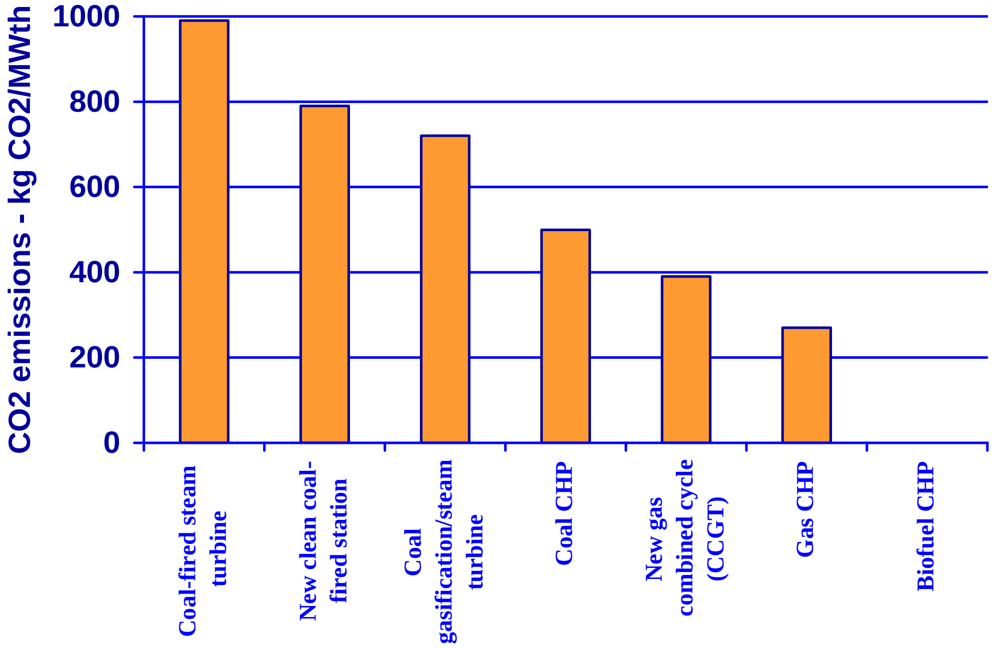
Biomass cogeneration accentuates many of the advantages outlined above and more extensive use of biomass cogeneration would contribute to a number of European policy imperatives, covering the environment particularly climate change, renewable energy and energy security, waste management, rural employment etc.

European countries are committed to challenging CO2 reduction targets. The EU is committed to reducing its CO2 emissions by 8% less than 1990 levels during the Kyoto first commitment period 2008-2012, and this burden is shared amongst member states. While cogeneration technologies in general offer CO2 savings, biomass cogeneration offers nearly full CO2 neutrality on a life cycle basis (see graph below).

The production of wastes of all types is growing in Europe and their management is an increasingly important issue. Currently over 60% of municipal solid waste in EU is disposed to landfill and incineration accounts for less than 20%. Regulations are in place to, firstly, reduce waste by recycling etc, and also to divert waste from landfill. This is for environmental reasons and because landfill capacity is running out. The European Environment Agency reported in 1999 that there was around ten years of capacity in the EU (although there was wide variation between countries). Waste water and sewage sludge amounts are increasing, due to increased urbanisation and water consumption rates. These wastes are coming under increasingly strict regulations, for example bans on disposal to landfill and agriculture land. Biomass cogeneration technologies suitable for using many types of waste materials at different scales already exist or are being developed. Some synergies are being explored, such as the use of waste water to irrigate dedicated energy crops.

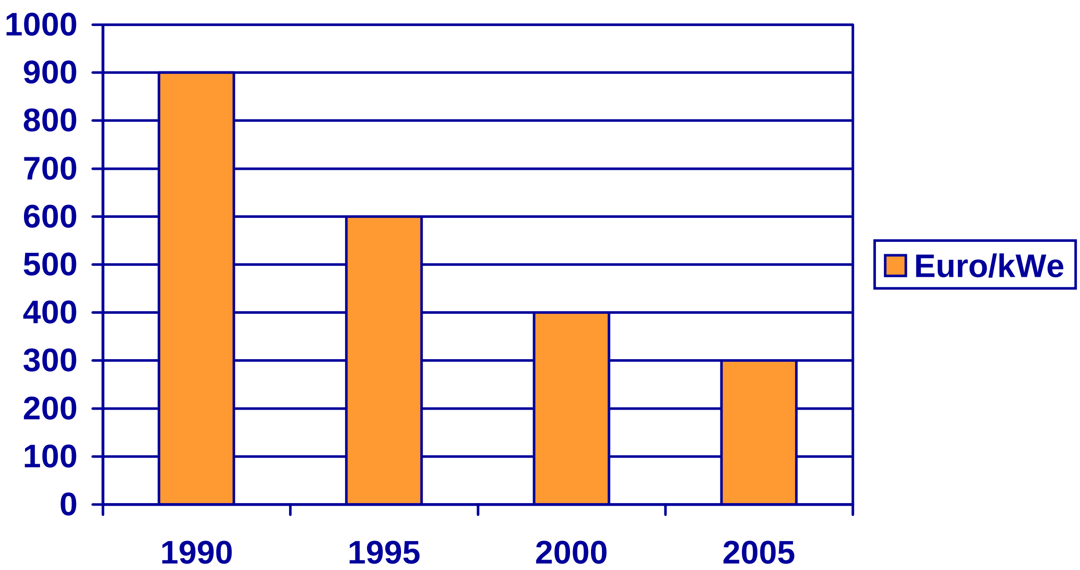
Another European imperative is employment, including the diversification of rural and farming activities. Many potential biomass sources lie in the agriculture and forestry sectors and could provide additional revenue and job opportunities.

Comparison of CO_2 emissions (source COGEN Europe)



It is also notable that capital costs for cogeneration are declining rapidly. The capital cost of biomass cogeneration is typically considerably higher (but fuel costs are often lower) than conventional cogeneration but a similar trend is evident.

Capital costs for 10 MWe engine- based CHP systems (source COGEN Europe)



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Why invest in biomass fuel supply and biomass cogeneration?

The primary reason for investment is to achieve an appropriate rate of return that is commensurate with the risk involved. Investors have other motives, and these include protection of the environment, compliance with regulations, fit with other business activities, social responsibility etc. These issues are explored below.

A well-designed and operated cogeneration scheme will always provide better energy efficiency than conventional plant. The cost savings are obviously dependent on both the capital and operating costs. Cogeneration plant is a high capital investment and there is a further premium for biomass cogeneration. The important consideration for the operating cost is the difference between the cost of the heat and power generated from the cogeneration unit and the situation that the cogeneration unit replaces. It will probably replace a heat-only plant and bought-in electricity. Biomass fuels with zero or low cost give very low operating costs once the initial capital investment is made.

Cheap electricity from cogeneration is important but is often a secondary criterion: it is a general rule that productive use of recovered heat is critical for financial performance. As a rough guide, cogeneration is likely to be suitable where there is a fairly constant demand for heat for at least 4,500 hours in the year.

A wide range of incentives reflects various environmental, energy security etc objectives. These are becoming more widespread and also tailored to the market than relatively straightforward capital grants. For example, there is a rapidly growing market in greenhouse gas emission credits and renewable energy certificates, which are backed respectively by emissions caps and mandatory obligations on utilities. Most of these incentives have considerable value and can make otherwise financially unattractive installations viable. However, to date most incentives have focused on electricity and heat has generally been excluded – this is because of the dispersed and complex nature of heat and its perceived unimportance.

The focus of national measures has often been to provide direct incentives for the power generated from renewable energy sources. This is in large part due energy efficiencies and the heat market being much more difficult to measure. However, broader mechanisms such as carbon and energy taxes and more sophisticated tools such as emissions trading are being put in place widely. These have wider effects on energy saving, energy efficiency and renewable energy. The extremely high efficiencies that biomass cogeneration offers may be rewarded, depending on the design of the instruments.

Increasing concern for the environment is also being reflected in regulations and targets in the waste management field. Regulations restricting landfill, open burning of wood waste and straw etc are increasingly tight. The European Landfill Directive has established a target of 65% reduction in biodegradable waste. Several countries have introduced landfill taxes (Austria, Belgium, France, Denmark, Netherlands, UK). Many thousands of industrial sites in Europe produce significant quantities of biomass residues and these are increasingly creating disposal costs. Using these materials for incineration, with cogeneration, is one possible disposal route.

The degree to which environmental drivers stimulate biomass cogeneration varies between countries. For example, in Bulgaria it was noted that some investors anticipate new incentives, regulations etc but these are not yet in place. Denmark lies at the other end of the spectrum: electricity generated by biomass CHP plant is subsidised directly, biomass fuels are exempted carbon tax, power utilities are obliged to use certain amounts of straw and wood for fuel, and organic waste is banned from landfill.

Sectors in which biomass cogeneration is established may also experience drivers to expand. For example, the majority of pulp and paper mills are self-sufficient in their energy needs, using by-products including black liquor to generate heat and power. However, new pulping and paper production technologies coupled with increased milling capacity have increased electricity demands substantially and have required the purchase of additional electricity from the power utilities. Work is underway to maximize the utilization of biomass by-products. One solution has been found to combine these with other local fuels to produce steam and heat in a utility sized power plant.

Many wood processing sites use dated equipment to combust wood for heat, and there appear to be commercial opportunities to retrofit and replace plant for increased heat and power for own use and / or export. Emission levels from such plant may also be high so increasingly restrictive regulations can be an important consideration. Mill or factory owners and operators may view export of power and / or heat as a secondary business. For example, several Slovenian wood processing factories are developing cogeneration plant to export heat and/or power to adjacent residential settlements, hotels or leisure facilities. These are examples of factories essentially diversifying from wood products into the energy business. It is notable that in all these cases reported in Slovenia, new plant planned will require purchase of additional wood residues for fuel, in addition to existing quantities of residues produced.

Opportunities to install cogeneration in wood processing sites are often not as commercially attractive as they appear at first sight, primarily because of low heat demand but other factors are important – some significant barriers are discussed in the following section.

Bioenergy in general has a unique link with land management. Bioenergy offers considerable benefits but only some of these may be financially rewarded in the short term. This area in fact more commonly causes financial penalties and increases risk for potential investors – these issues are reviewed in the following section.

In many countries, such as Turkey, Greece, Slovenia etc, the existing market in rural fuel wood employs many people and generates significant economic flows (cash and non-cash) in the rural economy. It is reported that it is generally well known that biomass has the potential to be an indigenous, environmentally benign energy source, financially benefiting rural economies. Some community based and non-government organisations may be interested to be involved in the development of biomass plant using fuel supply based on these traditional routes.

The creation of biomass fuel demand may help in three land management areas:

- Silviculture, especially early (pre-commercial) thinning

- Forest fire prevention
- Abandoned agriculture land

Good silviculture practice includes early and regular thinnings, which generates large quantities of small dimension material. However, this material typically has no market and is often heavily grant-supported or simply not undertaken, to the detriment of future timber quality and yield production. The development of a demand for early thinnings produce would create some financial return and help ensure that these practices continued and are perhaps even extended.

A related issue is cleaning operations to reduce biomass accumulation and fire hazard in forests in Southern Europe. Fire causes enormous areas of land to be degraded and has repercussions on forestry, tourism, watershed management, soil erosion etc. Developing biomass fuel markets in these countries could provide some financial incentives for improved land management practices which would help to reduce the incidence of fires. This would have huge benefits, however, these benefits are indirect, and thus rather difficult to understand, encourage and reward.

In Slovenia, it is reported that there are substantial areas of abandoned agriculture land, these areas are not managed, are becoming overgrown and are an environmental management issue. Creating demand for biomass fuel would help to bring these areas back into economic exploitation and have some environmental benefits. Furthermore, development of new dedicated energy crops and / or an energy market for residues from exiting crops, would help farm income and reduce the rate of land-abandonment.

There are several fundamental difficulties common to the above issues. Firstly, biomass fuel supply can only be a small part of long term solutions – there are few individuals or organisations that can take the necessary broad and longer term view and actions. Secondly, it is difficult to reward a biomass cogeneration facility investment for land management benefits – this is a big step in internalizing of costs/benefits.

The supply of biomass fuels is more labour-intensive than supply of fossil fuels. Reliable quantitative data are scant but this general conclusion can be made based on the fact that fossil fuel supply industries are centralised and mechanised to an extent that may never be possible with biomass fuels. Perhaps more importantly, the distribution of jobs in bioenergy and those in fossil fuels differ. Bioenergy CHP plants will be relatively small scale and dispersed. Biomass fuel supplies provide rural employment. This is considered to be an important social benefit but it also contributes to higher costs and thus lower financial competitivity of biomass fuels.

While biomass fuel supply is an area fraught with difficulties, experience in Scandinavian countries has shown that biomass fuel supply can integrate well with existing round wood and agriculture production activities, providing additional revenue opportunities for existing forestry and agriculture operators / contractors and / or opportunities for new specialised biomass fuel supply specialists to be established. Learning and technical developments take place with increasing scale of activities leading to reduced prices, improved quality (ie conformance to specific standards) and more dependable supplies.

6. The barriers to biomass cogeneration

It is useful to review the experience of the wider cogeneration industry. COGEN Europe provides a succinct overview of the difficulties that the industry is facing (2001) and this is reproduced in the box below. The barriers outlined in the box are very significant and the cogeneration market in Europe is currently static and many believe that EU targets will not be achieved. This section reviews those issues that are specific to biomass cogeneration.

Changing barriers to the cogeneration industry

In 1995, COGEN Europe published a study "The Barriers to Combined Heat and Power in Europe" that demonstrated that many of the barriers to further development of cogeneration derived from the existence of monopolistic electricity markets. The most frequent barriers were:

- Too low tariffs for surplus cogenerated electricity sold to the grid;
- Very severe tariffs for standby power and, in particular, back-up power supply;
- Lack of freedom to 'wheel' (third party access) or, when allowed, too expensive to consider;
- Technical barriers. Cogeneration schemes need to fulfil certain technical and safety requirements for proper operation. Sometimes the procedures take too long and are not transparent enough.

In a liberalised market, these traditional barriers do not exist, because cogenerators are free to sell to any customer. Provided the market is properly structured, cogeneration can provide the most cost-effective option for producing electricity when the savings from heat utilisation are taken into account. However, reality has shown that the ongoing process of liberalization brings new barriers if the market is not structured in a way that allows fair treatment. Recent experience brings the following set of barriers:

- Due to recent and on-going changes in the legal frameworks, uncertainty is playing a very dissuasive role in the investment decisions;
- The first effect of liberalisation has in many cases been a considerable reduction in the electricity prices. In some countries the prices have been lowered below cost and this makes it unprofitable to invest in or run cogeneration plants. This is aggravated by the willingness of some governments to pay large sums of stranded cost to the electricity utilities and the massive overcapacity in old, inefficient power plants;
- Closely related to the last point, environmental costs are almost never included in the energy prices and neither are avoided costs for the use of the network;
- The adopted systems for access to the network are proving to be a new barrier in more than one country. Without going into great detail, it can be said that they are often very complicated to understand and expensive.
- Because of the need to take a relatively medium term view (cogeneration is a relatively expensive capital investment), volatility and uncertainty in energy markets, tariffs or prices may deter potential investors. To assist investors evaluate the impact of price changes requires that clear and transparent policies are used in the regulation and operation of energy markets, leading to relative stability and predictability of energy prices.

One important issue, which is clearly evident from BIOCOGEN's survey, is the lack of data. The uncertainty for cogeneration investments in general, noted in the box above, is compounded by the fact that biomass is not a traded commodity like oil or gas though some international trade is developing (Hillring 2003). This raises a number of additional questions, particularly for those investors that are not dealing with materials that are self-generated.

Reliable quantitative resource data is scarce. This is coupled with (and due to) the informal nature of existing wood use – both domestic use of wood and factories use of wood and agro-industry residues for energy purposes is often unrecorded. The picture that is presented to policy makers and energy industry investors is that the market is small, uncontrolled, old fashioned and financially unattractive. Better data would allow more accurate observations to be made.

The data on resources that does exist may also be misleading since secondary uses often exist, such as wood offcuts used in particleboard manufacture and sawdust used in agriculture etc. In order that biomass CHP investments are commercially attractive, it is critical that fuel feedstock has a low price and that there is no risk of a big increase in price. Existing and anticipated competing uses of wood and agro-industrial residues are important.

A unique aspect of many biomass materials is their seasonality. The seasonality of forestry and agriculture is seen to be a key risk, for both establishing viable fuel supply businesses and for maintaining year-round fuel supplies to potential CHP plant.

In comparison to fossil fuels, biomass fuels are characterised by their low-density and sources of biomass are small, dispersed, disparate and seasonal. Biomass fuels may be collected from, for example, individual farms covering a wide geographic area. Sources are relatively very small in comparison to fossil fuel extraction industries, with the possible exception of the largest pulp and paper or wood processing units. These issues all contribute elements to fuel costs - logistics, contracting, transport, fuel preparation, storage etc. While some low cost biomass fuel sources may be found – wastes that incur a disposal cost – the prices of biomass fuels are often significant.

Contracting adds significantly to cost. International quality standards etc for fossil fuels are well developed and widely recognized and standardised fossil fuel supply contracts make transactions straightforward. However, biomass fuel supply contracts need to be written anew for virtually every biomass cogeneration plant, with the exception perhaps of well-developed wood and straw fuel markets in Scandinavia.

Environment is an important driver, as noted earlier. But there may also be opposing restricting effects. In some countries, the general public do not always perceive bioenergy to be as “deep green” as other renewable energy technologies such as wind and solar. This is the case even for the “cleanest” sources of biomass: uninformed people are unaware of the carbon neutrality of biomass and some express the view that bioenergy is “burning the trees”. As with all developments, there is potential for “Not-In-My-Backyard” (NIMBY) opposition to bioenergy plants, based on aesthetic appearance, increased traffic in the locality etc.

High capital cost of biomass cogeneration plant is a major disincentive to investors. While some technology is proven, a lot of technology is in research, development and demonstration phases, and the technology risk is unacceptable to most investors.

As noted above, a rough guide for investment in cogeneration is that there should be a fairly constant demand for heat for at least 4,500 hours in the year. This is a very onerous requirements for many potential biomass cogeneration sites. Many agro-industries operate only for short seasons, for example olive oil mills typically operate only 3-4 winter months.

In addition to the difficulties noted in the box above, it must also be mentioned that district heating faces a unique set of challenges. District heating networks require extensive civil works with all the attendant cost and time requirements. District heating systems have very high upfront capital cost, require a long term view, and have historically been owned and funded by public and/or municipal authorities. This type of funding is no longer as readily available as it has been in the past.

An important consideration is that the core business for the wood or agro-industry plant owners and managers is not energy. There is likely to be a list of desired improvements to their products and processes to make these products. If a capital sum is available for investment, improvements to their core business are likely to take precedence over their energy plant. Sites that are market leaders in their field, with limited scope for further product improvement, and are perhaps more likely to examine diversification opportunities and view energy export as a new business opportunity.

It was noted that universities do not educate engineers about renewable energy technologies. Appropriate skilled staff will be necessary for future developments. Also, these individuals may in the future hold decision-making roles in energy plant investment. Giving them awareness and knowledge of successful renewable energy technologies is considered important.

The upper size limit of biomass plants is lower than fossil fuel fired plants, because long-distance transport of low-density biomass fuels is generally not considered (for financial or environmental reasons). There are limited opportunities to achieve economies of scale with bio-energy. Thus, to achieve favourable power and heat generation costs, technology with high fuel conversion efficiency is selected. For example, gasification technologies enable higher electrical conversion efficiencies than conventional combustion boiler plant. There is also considerable interest in pyrolysis. However, these advanced technologies are at development and demonstration stages and there are technical risks and costs are still high.

Although cogeneration is a long-term investment, with equipment lifetimes of up to forty years, in most cases it has to compete with other potential business projects that are expected to yield rapid returns. In addition, since cogeneration is often not considered to be core business plant, it receives a lower priority. These factors may mean that schemes fall outside a company's investment criteria for utility plant so alternative methods of financing often need to be investigated if cogeneration is to be implemented. These include third party finance, ESCOs, plant leasing. These routes are practiced to varying degrees in the fossil fuel cogeneration market. However, most sectors of the biomass cogeneration industry are as yet too undeveloped technically and too high risk for these types of arrangements to be possible.

There are many incentives for bioenergy CHP throughout Europe but, colloquially expressed, the “devil is in the detail”. Even if incentives aim to promote bioenergy CHP, ill-design may result in poor uptake. Incumbents in the power industry – the international utilities – will always seek to maximise the benefits to them and maintain the status quo. For example, in the case of the forthcoming emissions trading Directive, work by COGEN Europe (2002) indicates that several fundamental characteristics (the focus on direct emissions from specific sites, the allocation of allowances for free, the generally prevalent view that allocation will be based on historical emissions levels) may all act against CHP.

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